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Electricity sector in Mexico: Current status. Contribution of renewable energy sources

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ABSTRACT

The challenge facing the world electricity sector is the cost incurred in maintaining the system and seeing to the environmental effects it causes. In Mexico the grid is supplied by thermal plants fed by oil products. Its great potential of renewable energies clearly shown in studies by national and international scholars has led the government to become more committed to take advantage of these energies. The goal is to reduce dependence on fossil fuels to generate electricity and to reduce the emission of greenhouse gases. In this article we analyse the current state of renewable energies, the conditions needed to foster them and the legislative changes already introduced to promote their greater part in the national electricity grid.

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Contents

1. Introduction

In recent decades the essential role of energy in social and economic development has been acknowledged. However, it must be pointed out that the current energy model does not allow a rhythm of sustainable growth for many countries owing to the

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imbalance between energy supply and demand and the volatility of oil and natural gas prices. Achieving a greater degree of independence from traditional energy sources and lessening the emissions causing the greenhouse effect are the topics that have led to much research directed at using renewable energies. In this paper the important role these energies can play in reaching these proposed aims is shown to be right and reasonable [1–7].

In Mexico the electricity system is based on high cost fossil fuels with supply deficiencies. In spite of the national interest in renewable energies in the last quarter of the last century, they have not undergone a significant growth as the country is an oil producer. Political and economic uncertainties of this fuel and the growing development of renewable ones on a world scale have renewed interest in installing them [8,9].

The National Development Plan 2007–2012 sets the rational and sustainable use of natural resources and the progressive diminution of greenhouse effect gas emissions as priority goals [10]. The aims of the energy policy of the country are to have a secure supply of energy, to diversify its primary energy sources reducing their environmental impact and to improve the competitiveness and efficiency of public companies. The installation of the most developed renewable energies (hydraulic, biomass, wind and sun) in the shortest possible time is considered essential to obtain these goals.

The combination of Mexico's great potential of renewable energies with the wishes of the industrial sector and the citizens has led the government to propose a special plan for a large scale exploitation of these energy sources [11–16]. The main objective of the plan is the generation of electricity, whether already connected to the grid or in installations in sites distant from the distribution grid, to meet the demand for energy.

2. Country overview

México is situated between latitudes 21°43′06″N, 14°32′27″S and longitudes 86°42′36″E 118°22′00″W. It borders in the north with the United States, in the southeast with Guatemala and Belize, and in the east and west with the Pacific Ocean and the Gulf of Mexico, respectively (Fig. 1).

Its geographical situation places it in one of the strips of land with the greatest solar radiation in the planet. Similarly, the currents in the Gulf of Mexico and the Pacific Ocean influence the air currents that cross the narrowest part of the Isthmus of Tehuantepec which is beneficial for important wind resources.

The country has a wide diversity of climates from the very hot (45 °C in the Sonora desert) to the very cold (−20 °C in some areas of Chihuahua), although for the most part temperatures oscillate between 15 °C and 26 °C. Another of the country's features is its "rugged" relief with mountainous areas, volcanic focal points, valleys, plains and plateaux. There is great tectonic and volcanic activity which gives rise to hydrothermal deposits offering marked geothermic and mineral wealth. Likewise, full, fast-flowing rivers and great lakes mean it has an important hydraulic potential.

Politically, Mexico is a federal democratic republic made up of 31 states and a Federal District. It covers an area of 1,964,375 km^2 and has a population of 106,682,518 inhabitants [17]. It has a free market economy. Foreign trade is regulated by free trade treaties with countries of North, Central and South America and with those of the European Union, Japan and Israel. The country's main sources of income are oil exports and tourism.

3. Energy structure

Mexico's energy structure is made up of the following primary energies: coal, oil (crude and condensed), natural gas, nuclear energy, hydraulic, geothermic wind and biomass (bagasse of sugar cane, wood and forest waste). The main secondary energies are coke and the liquid gases from oil, gasoline, naphthas, kerosene, diesel, gasoil, dry gas and electricity. These energies are used to satisfy the needs of the traditional consumer sectors (residential, commercial, industrial and transport).

In 2008 primary energy production was 10,522 PJ [18], oil-generated (89.9%), hydraulic energy (4.4%), biomass (3.3%) and coal (2.4%) (Fig. 2).

The state company Petróleos Mexicanos (PEMEX) is the sole producer of the oil and gas resources largely found in the sea of the Gulf of Mexico and the coastal land areas adjacent to the Gulf. Only the deposits, where 68% of the known resources lie, are being exploited.

Between 2000 and 2004, the average annual oil production (crude, naphthas and condensed) was more than 3000 barrels a day. From 2005 onwards there was a slight reduction in crude oil production and in 2008 it was down to 2793 barrels a day, an 8.3% drop on that recorded in the previous year [19]. At the current rate of production the known reserves of crude oil will be exhausted in 9.2 years and those of natural gas in 9.7 years time.

At the end of 2007 it was calculated that the known reserves reached 14,717 millions of barrels of oil equivalent (Mbpe), 71% crude, 12% condensed and plant liquids and 17% dry gas. The probable reserves are about 15,255 MMbpce and possible reserves reach 14,621 MMbpce, the total sum being 44,593 MMbpce (70% crude, 10% condensed and plant liquids and 20% dry gas liquid equivalent). The ratio reserves-production for the known reserves is 9.2 years. The sum of the three types of reserves gives 27.7 years. 32% of the known crude reserves are to be found on land and 68% in the sea, while 62% of natural gas deposits are found on land and 38% in the sea [20].

For the last 15 years the refining capacity of Mexico has remained more or less stable. Petrol imports have undergone a marked growth and reached 40% in 2006.



Fig. 1. Geographical situation of Mexico.

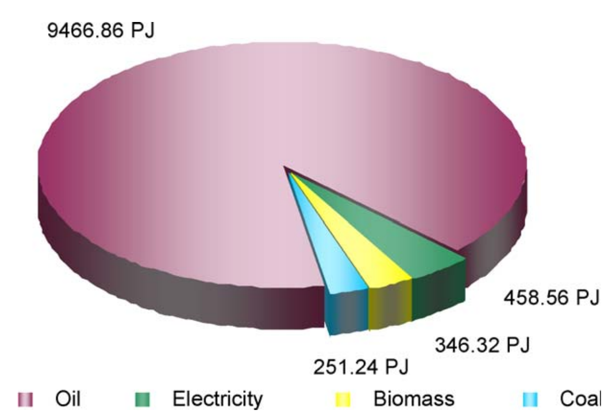


Fig. 2. Primary energy production in México in 2008.

From 2003, natural gas production has increased sustainably to reach 7211 millions of cubic feet daily (Mpcd) in 2007 and 8054 MMpcd in 2008 (17.3% increase on the previous year).

In Mexico, the main sources of biomass are sugar cane and wood waste products which together contribute 346 PJ.

4. Electricity sector

Eighty years ago the electricity service was run by three private companies which supplied 38% of the total population concentrated in urban areas. The quality of supply was poor with frequent cuts and high rates. In 1937 the federal government set up the Federal Electricity Board to increase the generation of electricity in reply to the situation. In 1960 the FEC contributed 54% of the total electricity generated. In 1971 installed power was 7874 MW, and 10 years later it reached 17,360 MW, while in 1991 it was 26,797 MW.

Generation, transmission, supply and distribution of the electricity system are state monopolies. There are two government companies responsible for these functions: the Federal Electricity Board (CFE) and Central Power and Light (LFC). The former is responsible for 80% of the national electricity system and the latter only sees to the central region of the country (20%).

The Mexican electrical system is co-ordinated by the Secretary for Energy (SENER), the Regulatory Board for Energy (CRE) and the National Board for the Efficient Use of Energy (CONUEE). The SENER is the body dependent on the Federal Government and in charge of co-ordinating the national energy policy. The function of the CRE is to regulate private participation in the electrical and natural gas sectors. The CONUEE has the goal of fostering energy saving and efficiency and promoting renewable energies.

In 1992 a very important amendment was made to the law for the public service for electrical energy to allow private investment to participate and thus increase the nation's electrical power. This change saw the appearance of the following participants: large foreign investors (LFI) for installations greater than 30 MW and small producers for installations less the 30 MW, self-suppliers and self-generators [21].

The LFI and small producers can only sell electricity to the Federal Board who undertakes its distribution. The following companies make up the LFI: Iberdrola, Transantla, Chubu Electric Power, Calcine, Mitsui, AES, EDF, Unión Fenosa, Tokyo Gas, AEP, Intergen, Mitsubishi and Kyushu Electric Power [22].

In 2008 the installed capacity in the country was 51 GW. Of the government installed power plants (CFE-LFC) 58.2% were thermal plants and 28.8% hydraulic. Renewable sources other than hydraulic, such as wind and geothermic, contributed 2.7% [23,24] (Fig. 3).

Of the 237 electric TWh produced in 2008 (Fig. 4), public owned companies contributed (CFE and LFC) 65.2% and the LFI the remaining 30.4% (Fig. 5).

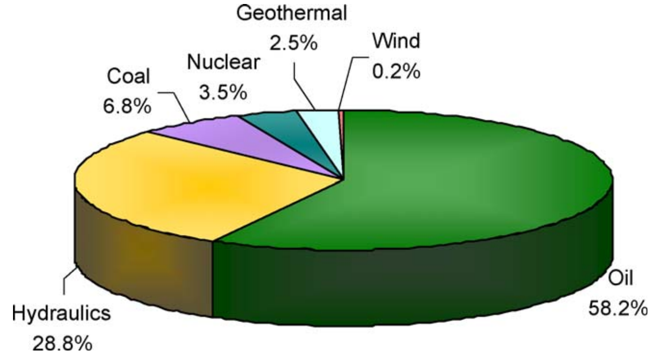


Fig. 3. Distribution of the energy sources making up the government owned companies installed capacity.

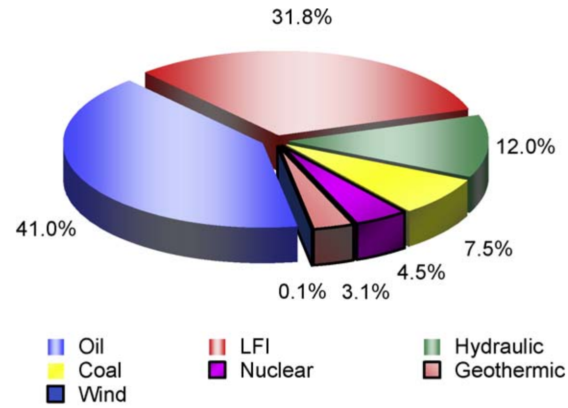


Fig. 4. Electricity generation by source in 2008.

The recent rise in generating power has been realized with plants using a combined cycle. These plants with their greater efficiency, smaller investment costs, taking less time to build than usual have meant larger imports of natural gas at a time of high prices for this fuel [25].

Today 97% of homes are connected to the grid which places the country at a level close to that of the developed countries. However, more than 3 million inhabitants, living for the most part in areas difficult to access, still lack electricity. It is, therefore, necessary to extend the electricity supply to these areas by using renewable energies in the cases where it is neither technically nor economically feasible to connect them to the grid.

4.1. Electricity consumption

In México, the market for electricity is divided into five regions. The northwest comprises the states of Baja California Norte and Sur, Sonora and Sinaloa, the northeast those of Chihuahua, Coahuila, Nuevo León, Durango and Tamaulipas. The centre-west is made up of the states of Michoacán, Nayarit, Colima, Querétaro, Jalisco, Zacatecas, San Luís Potosí, Aguascalientes and Guanajuato. The states of México, Morelos, Hidalgo, D.F. Puebla and Tlaxcala are the centre. In the south and southeast are Campeche, Chiapas, Guerrero, Oaxaca, Quintana Roo, Veracruz, Yucatán and Tabasco. Out of these five regions the northwest is the biggest consumer because of its climate. It is followed by the centre, the centre-west, the south-southeast and the northeast in this order [26] (Fig. 6).

In 2007 national consumption of electricity reached 180.5 TWh (Fig. 7). The residential sector took 45.83 TWh. The main uses were cooking of food, heating water, heating and lighting.

The service sector demand rises to 6.78 TWh/year, a value that is equal to 3.8% of the total electrical energy sales of the country.

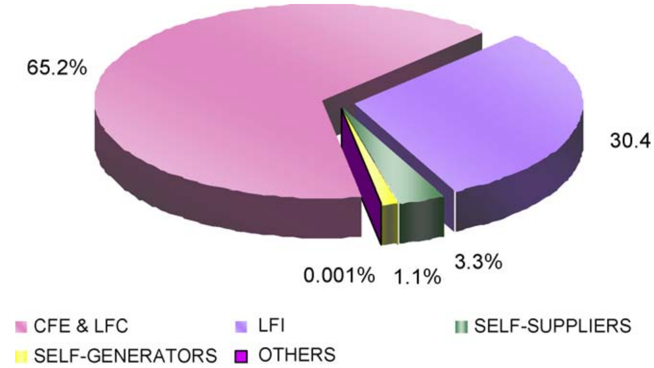


Fig. 5. Participation diagram of electricity generation in 2008.



Fig. 6. Division of the electrical market.

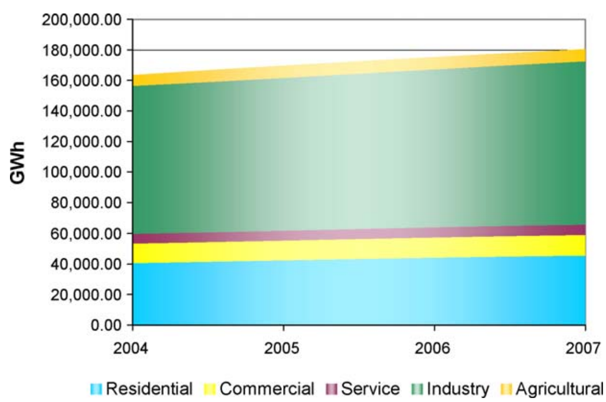


Fig. 7. Electricity consumption by sectors in 2007.

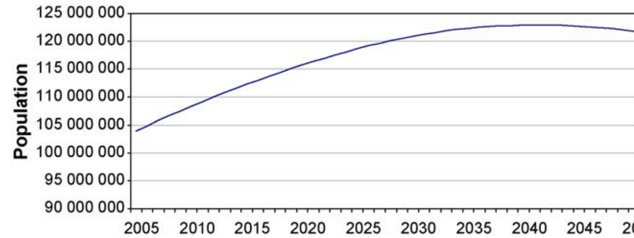


Fig. 8. Population growth in Mexico 2005–2050.

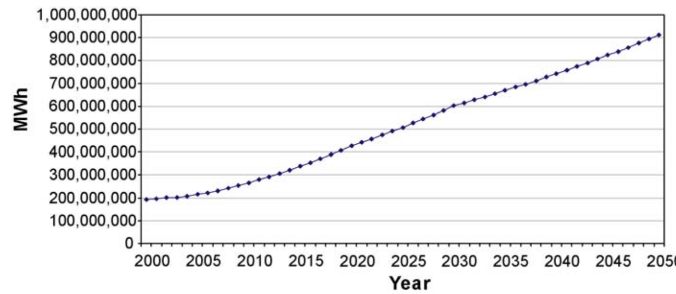


Fig. 9. National growth in electricity consumption.

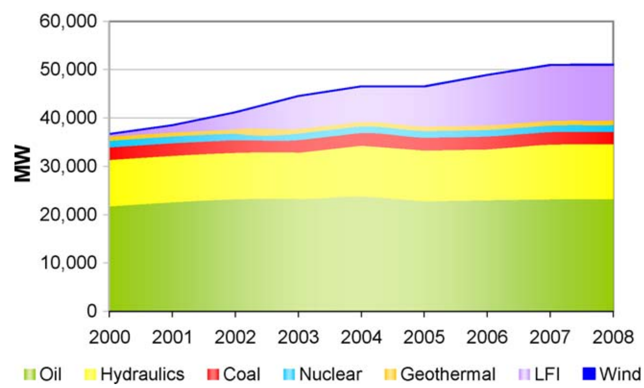


Fig. 10. Growth of the electrical sector in the period 2000–2008.

Industry is the main consumer and can be divided into large industries and medium-sized businesses. The latter is authorized to produce its own electricity supply. By subsectors, consumption from the highest to the lowest is as follows: glass, steel, cement, sugar chemical, mining, paper and cellulose, petrochemical, beer, bottled water, building, car, plastic, aluminium, fertilizer, tobacco and others. In 2007, electricity consumption was 106.62 TWh/year, 67.79 TWh for medium-sized businesses and 38.83 TWh for large industries.

The agricultural sector takes up 4.3% of the nation consumption of electricity and is mainly used for activities related directly with agriculture and cattle farming.

4.2. Growth

The growth of the electricity sector has undergone a faster growth than the population. Currently the growth rates of the population and electricity generation are 0.8% and 4.4%, respectively. The National Population Committee (CONAPO) foresees an important growth in population until 2040 and from then there will be a period of stability and even moderate reduction in the total population [27] (Fig. 8).

It is calculated for the future that the growth in demand will be 4.9% until 2020, 3.5% until 2030 and 2.1% till 2050, year in which consumption will be close to 900 TWh [28]. The areas where the greatest growth in demand is foreseen are those dedicated to tourism, especially in the peninsulas of Baja California and Yucatán, as well as the industrial estates in the north of the country [29] (Fig. 9).

The growth of the national electricity system in 2008 was 77 MW, 0.15% more than the power installed in 2007 [30] (Fig. 10).

4.3. Emissions

The electricity sector is responsible for almost a third of the CO_2 emissions of the country [31,32]. The most recent data are from the report "Atmospheric emissions from the electricity plants in North America" by the North American Environmental Committee in 2002. They calculated that the sector emits 55% of the sulphur dioxide (SO_2) and nitrogen oxides (NO_x), and between 27% and 30% of the carbon dioxide (CO_2) ones [33,34]. The percentage quantities of the emissions produced in generating electricity with fossil fuels are shown in Table 1.

Table 1
Percentage contribution of emissions by fuels in 2002.

Fuel	SO_2	NO_x	CO_2
Coal	21%	47%	22%
Oil	79%	35%	60%
Natural gas	0	17%	17%
Others	0	2%	1%

In 2002, the total CO_2 emissions from the industrial commercial, residential, fish farming and transport sectors rose to 389 t. The country occupied the twelfth place in the list of nations with the highest CO_2 emissions [35,36].

5. Energy policy

One of the central axes of Mexican policy is sustainable development. To achieve it, it is proposed to foster the efficient use of energy as well as the use of technologies that allow the environmental impact generated by traditional fossil fuels to be reduced. By these means they are attempting to reconcile the need to consume energy with the protection of natural sources. To succeed it is essential to take advantage of the great potential of the nation's renewable energies, which necessitate a legal framework that makes it feasible and an energy policy that encourages it.

For decades Mexico has exploited its native fossil fuels (coal, oil and its derivates). At the present the energy sector depends mostly on them. As mentioned, its known oil reserves are 14,717 MMbpce. The known reserves of coal have been calculated at 100 million t and the probable ones at 650 million of t. However it is thought that thermal coal will only serve to cover the demand of the two thermal coal plants in operation during their working life.

Energy policy is regulated by the Secretary for Energy (SENER). His department drew up several laws pertaining to energy: the organic law for Federal Public Management, the law for the Regulatory Energy Committee, Internal Regulations for the Energy Secretary, Internal Rulings for the National Committee for the efficient use of energy and the official Mexican regulations with respect to electricity matters, energy efficiency, thermal efficiency natural gas and nuclear safety [37].

The CRE is in charge of regulating energy and is responsible for granting licences in the management of activity development in the sector. This control is under federal jurisdiction and looks at technical and economic matters, among which is market stimulation.

On the 27th June 2007 in the official federal bulletin the contract for interconnection to solar energy on a small scale was published. It is applicable to all solar energy generators with a power equal to or less than 30 kW.

The law for the Exploitation of Renewable Sources (LAFRE), is one of the more important among those whose aim it foster the development and use of these energies. As a goal for 2012 the LAFRE aims at an 8% participation of renewable energies in the total electricity generated, exclusive of the large hydroelectric plants. In this plan it is foreseen that approximately 60 million dollars a year will be earmarked for promoting public and private investment in projects to generate electricity for public use using competitive technologies. Moreover, a further 30 million dollars a year will be for fostering other less developed technologies and for encouraging national technological development and research, regional social and economic development and that of the most backward sectors of the population [38].

The LAFRE does not concern itself with bio-fuels, since there are incentives for them established in the Law for the Promotion and Development of Bio-energies passed in February 2008. This law promotes the use of ethanol and other liquid bio-carburetants [39].

Official Mexican Norms (NOM) for environmental matters are a tool that allows the corresponding authority to set up requirements, specifications, conditions and procedures and to regulate the exploitation of natural resources for economic purposes. The NOM also play an essential part by creating a climate of legal certainty and in promoting technological change to achieve more efficient environmental protection. One of the most significant norms regarding renewable energy exploitation, though still in its planning stage, is the PROY-NOM-151-SEMARNAT-2006, that establishes the technical specifications for environmental protection during the building, running and closing of wind electrical installations in cattle and crop farming and untilled land areas [40].

6. Renewable energies in the electrical sector

It has already been noted that these sources of energy, besides guaranteeing cost stability, offer social benefits, since they promote regional development by generating employment, improving the quality of life in isolated areas, reducing environmental impacts and exploiting the opportunities for financing for clean energy projects from international bodies [41].

The chief government institutions taking part in the development of renewable resources are the following:

- The Secretary for Energy (SENER).
- The Regulatory Committee for Energy (CRE), that regulates and grants licences for the generating of energy.
- The National Board for the Efficient Use of Energy (CONUEE) fosters energy saving and efficiency and the use of renewable energies.
- The Institute for Electrical Research (IIE) develops studies for non-conventional energies.
- The Federal Electricity Board (CFE), the company responsible for the supply of electricity to the public.
- Light and Power for the Centre (LFC), a company with the same functions as the CFE.
- The Secretary for the Environment and Natural Resources (SEMARNAT), who draws up environmental and natural resource conservation policies.
- The Secretary for Social Development (SEDESOL), who promotes projects for the exploitation of renewable energies.

6.1. The current situation

Renewable energy and energy efficiency are key factors in the country's sustainable development. This is why programs already in existence are being strengthened such as the spreading of energy saving and efficiency moves within the federal government itself, national energy saving awards, and the promotion of the massive use of solar collectors for hot water sanitation.

At the present time the CFE is looking at the possibility of installing about 3.2 GW of renewable sources (wind, hydraulic and geothermal). For the auto-consumption modality with respect to industrial use and public lighting, there are already wind and hydraulic projects as well as for obtaining biogas produced from anaerobic digestion of municipal solid waste and manure.

It is worth mentioning the following among the actions taken to promote renewable energies [42]:

- Plan for Renewable Energies on a large scale of the SENER to install 100 MW from wind and 300 MW from hybrid installations (generation using mixed renewable sources or renewable and fossil ones).
- Action Plan to Remove Obstacles to the Installation of Wind Energy (GEF/PNUD/SENER-IIE) in which the SENER by means of the IIE looks at the development of the Regional Centre of Wind Technology in Ventosa, Oaxaca.
- There is the decree Factors for a Policy to Promote Renewable Energies, to stimulate projects with the Clean Development Mechanisms (CDM) in the Framework of the Kyoto Protocol and the drawing up of a National Program for Rural Electrification by way of renewable energies in the states of Oaxaca, Veracruz, Guerrero and Chiapas.

Currently, only a small fraction of the renewable resources is used to generate electricity and their contribution reaches 14.6% (12% hydroelectric, 2.5% geothermic and 0.1% wind).

6.2. Hydraulic energy

This is the most exploited renewable resource in Mexico. At the moment there are some 4000 dams that generate 19 TWh/year.

In 2005, the national hydroelectric potential was estimated at 5.3 GW, of which 3.2 GW corresponded to mini-hydraulic. The CRE, pointed out that the generation of electrical energy could reach 80 TWh.

In the states of Veracruz and Puebla, the potential rises to 400 MW which can generate nearly 3.5 TWh/year.

Chicoasén, the largest hydraulic plant in the country, has 2400 MW power installed and is situated in the state of Chiapas. On the first of March 2007 the plant "El Cajón" began working in the state of Nayarit with 750 MW of power, one of the most important projects in recent years. It was the most polemical in the history of hydraulic policy in Mexico because of public opposition from the beginning of its construction and it gave rise to a heated discussion for economic, political, social and environmental reasons.

At present, the plant "La Parota" (900 MW) is under construction and is situated in the state of Guerrero. Its rejection by ecologist groups has delayed its termination but it is expected that once it is finished it could generate annually 1529 GWh and avoid 0.94 Mt of CO_2 emissions.

6.3. Wind energy

In studies carried out by National Renewable Energy Laboratory (NREL) and several Mexican institutions it is estimated that national wind potential is more than 40 GW. The region of the Isthmus of Tehuantepec is one of the best regions on a world scale for the generation of electricity from the wind.

Due to the capacity limits that the installation of wind farms in Oaxaca could cause, the CRE carried out the procedures necessary for the CFE to construct a high tension line suitable to absorb the electric generation of wind farms in the area with a power around 1–1.5 GW.

In the LFI modality this infrastructure has promoted the installation of 1.5 wind GW which is expected to begin working in 2010.

Despite the existence of important national resources, wind energy still plays a small part in the electrical sector of the country. The inauguration in 2007 of the first wind farm on a large scale (La Venta II with 83 MW) was the largest contribution of this kind of energy in Mexico. It is today the wind farm with the greatest power output in the whole of Ibero-America [43].

The SENER has planned to install more than 500 MW of wind power in Oaxaca in the LFI modality in the next years which would allow output to reach 590 MW in 2014.

Currently, the wind farms of La Venta III, IV, V, VI and VII (each one of 100 MW), programmed to start operating between 2009 and 2012, are either under tender or at the design stage. With these farms the Isthmus of Tehuantepec could count on a total 585 MW of wind power installed by the end of 2012 [44].

6.4. Solar energy

Despite its huge potential it is still not the one most installed. 75% of the territory receives, on average, 5 kWh/m^2 a day. The states close to the Pacific Ocean coast are those with the highest radiation reaching 7 kWh/m^2 a day, compared with 3 kWh/m^2 a day for the rest of the country. In 2006, 839,686 m^2 of solar collectors were installed for sanitary hot water and 17,633 kW in photoelectric modules for rural electrification, communications and water pumping. It is expected that in 2013 there will be 25 photoelectric MW available to generate 14 GWh/year.

The most important installation in the country is part of the hybrid, electric, wind, solar, diesel plant in San Juanico (state of Baja California South). It is made up of 17 photovoltaic kW, 100 wind kW and a diesel motor-generator of 80 kW. In Agua Prieta Sonora, a desert area with a high rate of sunshine, a thermoelectric solar field of 30 MW is being built and is expected to go into operation in the summer of 2009.

6.5. Biomass energy

Bio-energy in Mexico is 3.2% of primary energy consumption. Its main sources are wood and sugar cane bagasse. In 2005 the sugar industry produced 5 million t of sugar and 56 million l of ethanol. The national production of ethanol began in 1999 in the state of Veracruz. Until 2007 there was no legal framework regarding bio-fuels and the ethanol was destined for the pharmaceutical industry.

With the passing in 2008 of the Law for the Promotion and Development of Bio-fuels, the sugar industry had the possibility to produce electricity and ethanol for the electric and self-propulsion sectors [39].

In 2005 the CRE authorized a project of 19 MW to generate 120 GWh/year with biogas, 70 MW to generate 105 GWh/year with sugar cane bagasse and a third one of 224 MW to generate 391 GWh/year with hybrid systems (gas oil–sugar cane bagasse).

The assessment of biomass resources available for energy purposes is between 2635 and 3771 PJ a year. Municipal, farming and forest solid waste products, suitable for generating electricity have been estimated at 73 million t. These waste products would allow an installation of 803 MW with an annual production of 4.5 GWh.

The company Bio-energy of Nuevo Leon developed a project of 7 electric MW, pioneering the use of biogas produced by anaerobic digestion of municipal solid waste, which went into operation in September 2003. It is currently being expanded with the aim of reaching 12 MW. The company "Monterrey Water and Drainage Services" holds two licences authorized by the CRE for the self-supply of electrical energy generated from biogas with a total power of 10.8 MW.

6.6. Geothermic energy

Mexico with its 960 MW of power installed and 7404 MWh/year occupies third place in the world for the generation of electrical power from geothermal sources.

The known reserves of this resource have been assessed at 1.3 GW and the probable ones at 4.5 GW. The geothermal deposits embrace the full scale of temperatures (high, medium and low). The current exploitation of the high temperature resource is 853 MW and of the medium temperature 107 MW [45].

Electrical generation from geothermal sources is regulated by article 81 of the "Law for National Waters", which states "The exploitation and use of or benefitting from subsoil waters in the form of steam or with a temperature greater than 80 °C, when it may affect an aquifer, will require previous permission for geothermic generation or other uses besides an assessment of environmental impact..." There are, however, no regulations for this article [46].

This energy source has not undergone major development owing to the high cost of the infrastructure and the specialised equipment needed to drill the wells in volcanic rock in extremely hot areas [47].

6.7. Tidal power energy

The Autonomous University of Mexico (UNAM) has calculated that in the Sea of Cortes (peninsula of Baja California), it would be possible to obtain a high generation of electricity from tidal energy due to the sea currents in the Canal of Infiernillo and to the hydrothermal vents (faults of distension in the sea bed) [48].

At the moment, the country has no electrical plants or projects under development of any kind to make use of tidal energy.

7. Analysis and strategies for the development of EERR (renewable energies)

With the goals set for the use of renewable energies in the public electrical sector, it is hoped to reduce CO_2 emissions around 6.3 Mt CO_2/year. The private sector also has plans to exploit renewable resources which in the medium term would allow for an additional reduction of 3.52 Mt CO_2/year (Table 2).

Among the chief obstacles to the greater use of renewable energies in the country are the production and investment costs of some technologies and the lack of incentives and financing mechanisms on the part of the government to put large scale projects in operation. Similarly the lack of industrial capacity and qualified workers means that the existing installations are not yielding their full potential. The possibility for these energies to be exploited by the private sector under the LFI modality has meant that some of these installations are at the planning stage.

According to the data of the Undersecretary for Energy Planning and Technological Development the potential for the reduction of greenhouse gas emissions reaches 81 million t of CO_2 annual equivalent. At a price of 12.13 $/t of CO_2 [49] this would generate revenues around 98 million de dollars coming from the Clean Development Mechanisms (CDM) as seen in the Kyoto Protocol.

In July 2007, Mexico had 32 CDM projects related with the energy sector, registered [41] (Table 3).

For the end of 2012, with an installed capacity of 3600 MW from renewable sources generating 12,500 GWh/year, an annual reduction in CO_2 emissions up to 3.9 Mt could be attained.

Table 2
Potential of emissions avoided by the use of renewable sources in the electrical sector.

Renewable energy	Power (MW)	Generation (GWh/year)	Reduce emission (Mt CO_2/year)
Projects of the government			
Wind	591	2098	1.29
Geothermial	125	1020	0.63
Hydraulic	3988	5494	4.33
Solar	30	53	0.03
Projects of private investment			
Wind	1076	3829	2.16
Biomass	495	3035	1.11
Biogas	42	197	0.05
Mini-hydraulic	172	571	0.2

Table 3
Projects registered in the Clean Development Mechanisms.

Type of project	Quantity	$T_{equivalent}$ CO_2/year
Hydraulic	2	86,254
Self-generators	1	3,619
Recovery of methane and production of electricity	25	421,533
Wind	4	1,393,341

8. Conclusions

Primary energy production in Mexico comes mainly from hydrocarbons.

Currently, renewable energies account for 14.6% (12% hydroelectric, 2.5% geothermal and 0.1% wind) of the total electricity generated in the country.

The exploitation of the high Mexican potential of renewable resources to generate electricity needs the correct, suitable, regulatory framework, made-to-measure for the country's needs to attract investment and a legal setting to consider social, environmental and economic aspects.

Technological development and economic and financial incentives to make renewable energies competitive for electricity production need greater co-operation between the public and private sectors.

It is essential to increase transport lines and distribution of the electricity system to integrate these alternative sources effectively into the grid.

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